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Publication date:
2013

Document Version
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA):
Larsen, T. J., & Aagaard Madsen , H. (2013). *On the way to reliable aeroelastic load simulation on VAWT's*. Poster session presented at European Wind Energy Conference & Exhibition 2013, Vienna, Austria. http://www.ewea.org/annual2013/

PO.ID 029

On the way to reliable load simulations on VAWT's

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Abstract

In this paper a method for reducing the complex three dimensional flow problem of a Vertical Axis Wind Turbine (VAWT) into a number of 2D problems. The specific focus is on the implementation into a full aeroelastic code including consideration of structural dynamics, dynamic inflow, tower shadow and dynamic stall properties, which is needed for a full load analysis relating to eg. certification of a VAWT turbine. Load comparison to measurements of simple tests a presented with fine results. Further on, principal load cases according to the IEC61400-1 are simulated for a fictitious 5MW VAWT turbine. The IEC61400-1 load cases, originally developed for Horizontal Axis Wind Turbines (HAWT's), are discussed regarding the application to VAWT's. The model has been fully implemented in the aeroelastic code HAWC2 and capable of handling full turbine flexibility.

Methods

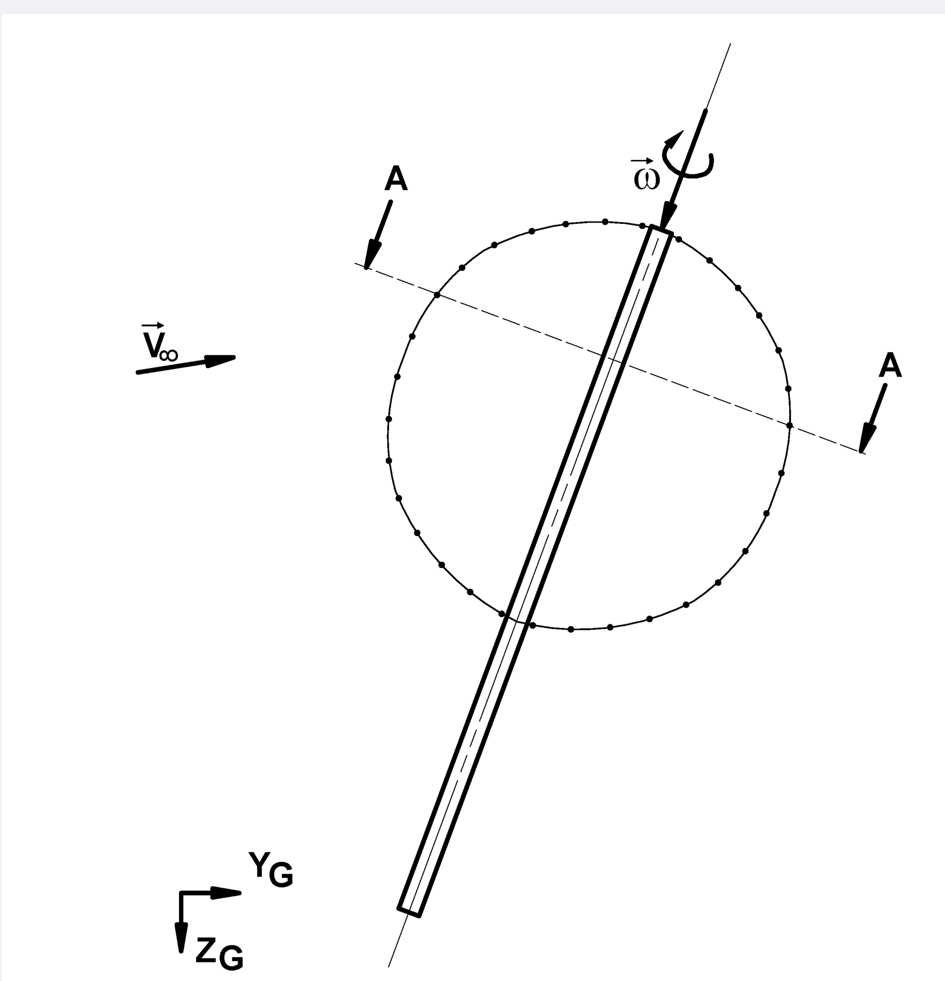

Figure 1. The three dimensional flow problem of the VAWT is subdivided into a number of 2D discs (A-A), each with calculation points around the full circumference.

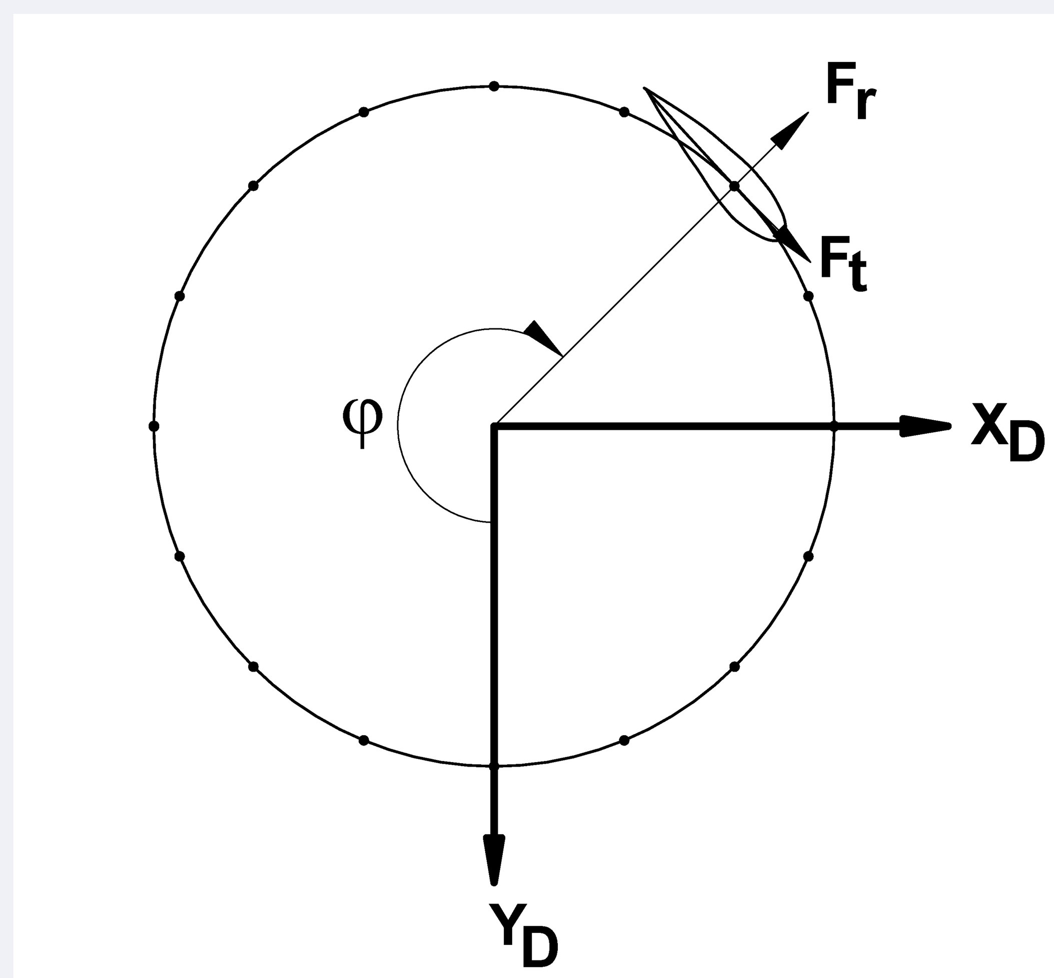

Figure 2. In each of these discs, the aerodynamic forces are calculated in each point as if the blade section was located there. This enables an actuator cylinder solution with correct inclusion of forces on the flow.

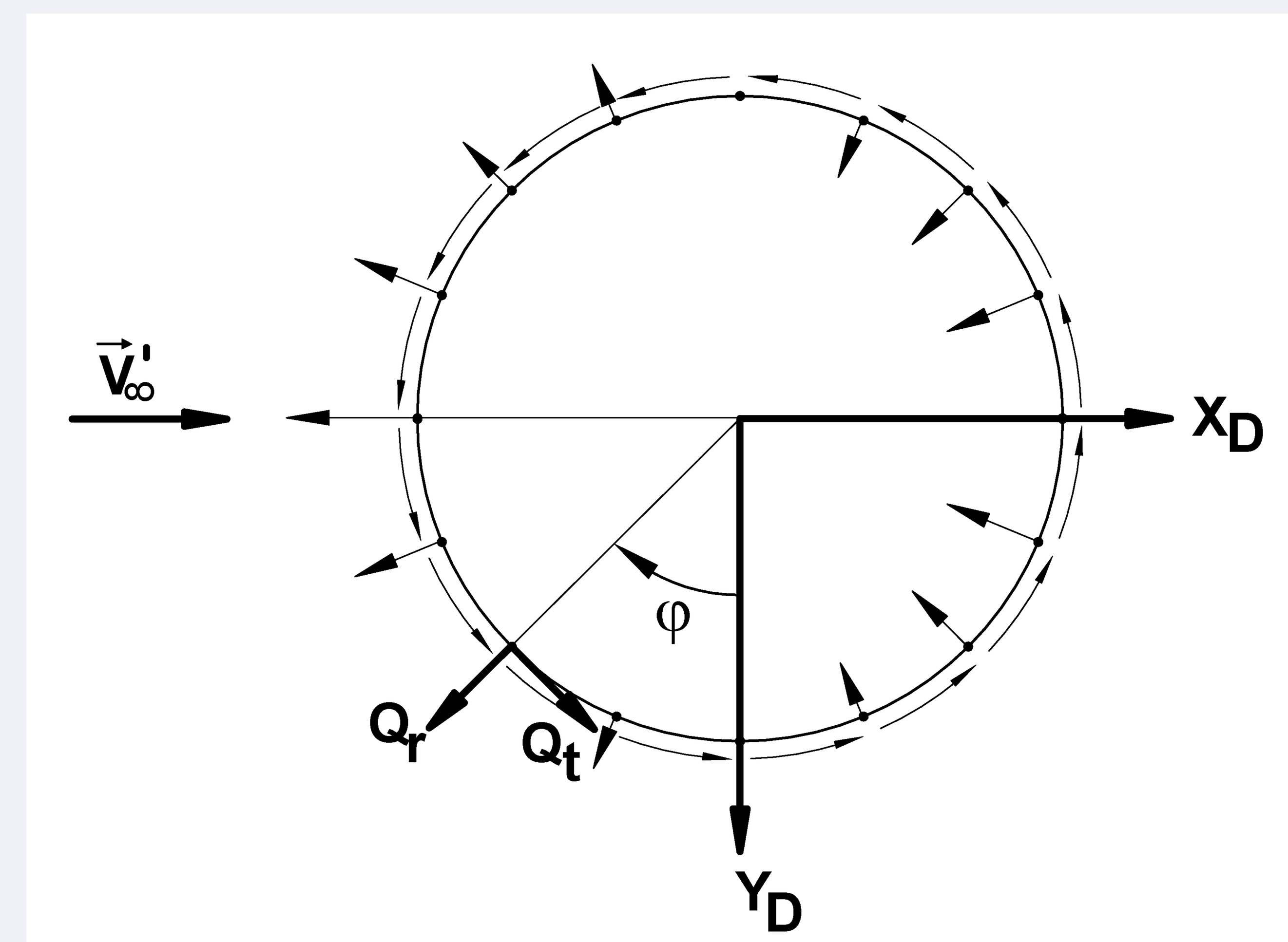

Figure 3. For the 2D case it is possible to find the steady state solution in a fairly easy way using a modified linear solution of the actuator cylinder approach. The benefits of this is a more physical correct solution than eg. a double stream tube method and a very computational efficient and fast approach compared to vortex and full CFD solutions.

Results

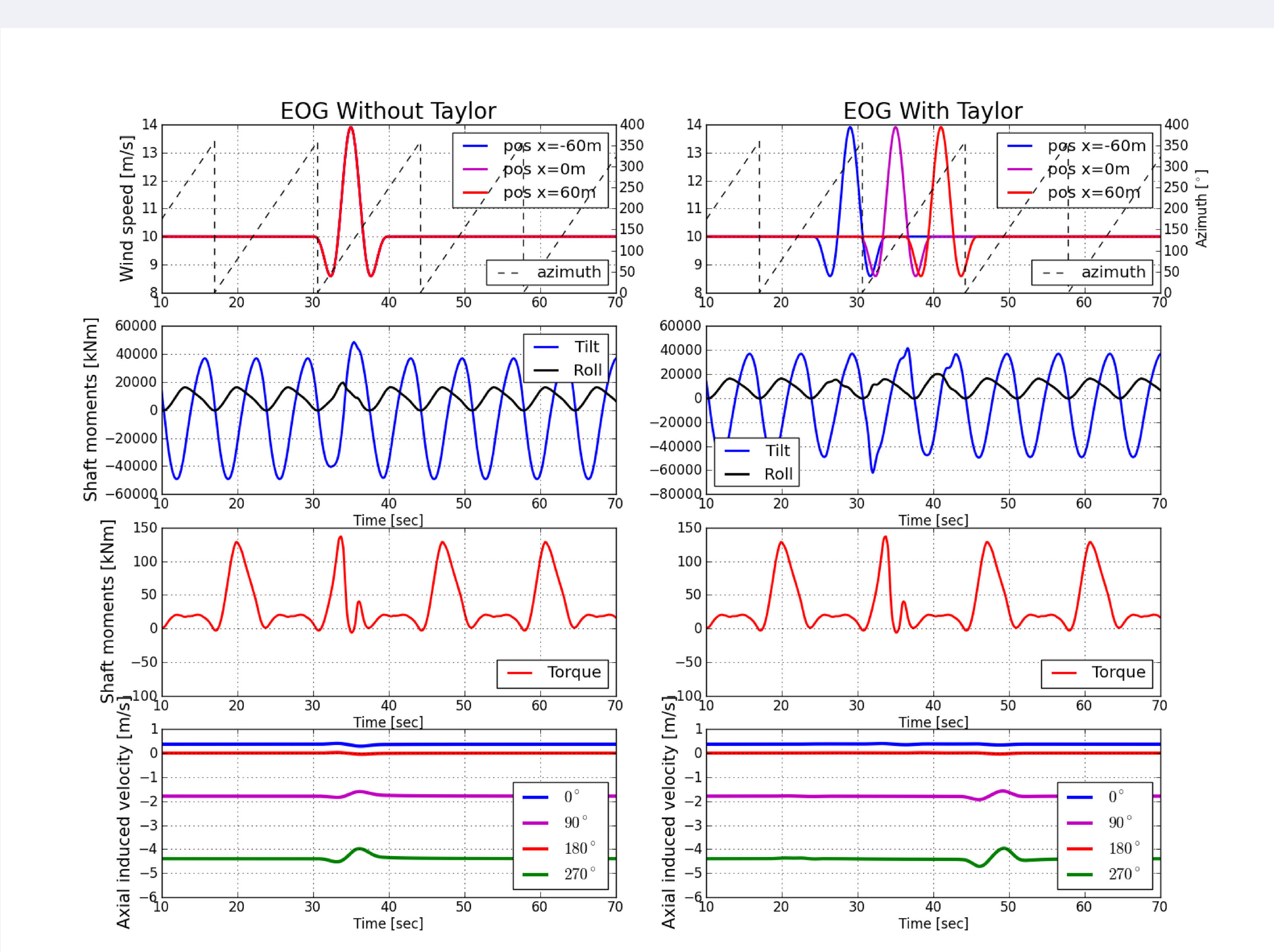

Figure 4. A simulation case with an extreme operating gust is shown. It illustrates the importance of using Taylors hypothesis in relation to VAWT's due to their extension in the along wind direction. The shaft moments are extracted below the rotor in a non-rotating coo.

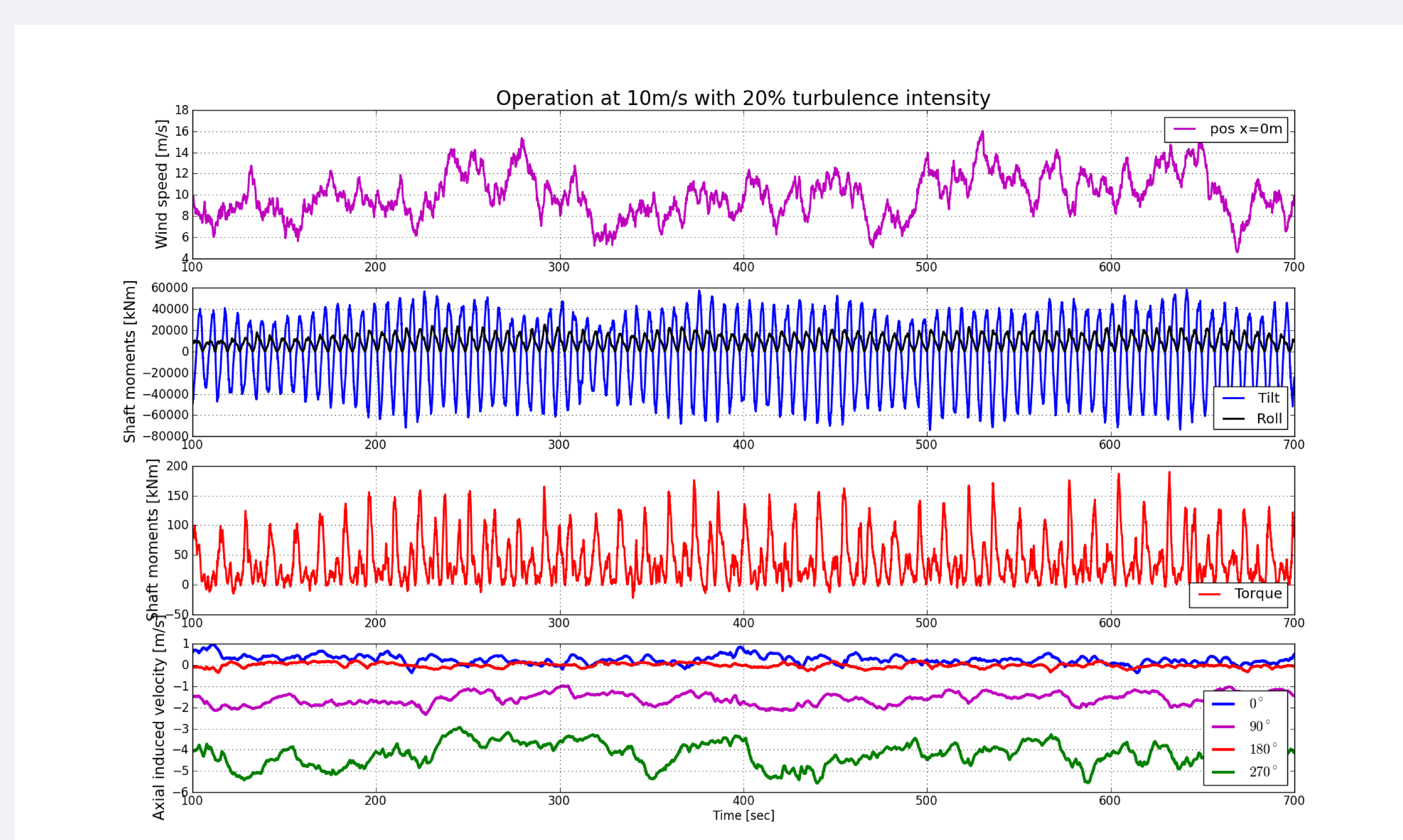

Figure 5. The response of the turbine in turbulent inflow is shown. Even though the load is still highly deterministic due to the two bladed configuration of the VAWT, the impact of turbulence is highly noticeable. The non-constant induced velocity at four selected azimuthal locations is also shown.

Conclusions

A new approach to simulate the complex flow of a VAWT has been presented with special attention to the implementation of a 2D actuator cylinder model in a full 3D multibody aeroelastic code for load simulation in time domain. The model has been extended from a quasi steady approach with a dynamic inflow model approach known from dynamic BEM formulations of HAWT simulations. Improvement of this model approach is still yet to be done, however initial results of full loading of a Darrieus VAWT is presented in both fully turbulent as well as gust load cases. In the present formulation of the IEC61400-1 standard, the gust load cases are specified as function of time and height only. In this paper, it is suggested to extend these gust case formulations between time and space using Taylor's hypothesis and the influence of this more physical correct approach is demonstrated for an extreme operating gust.

EWEA 2013 VIENNA EUROPE'S PREMIER WIND ENERGY EVENT 4 - 7 FEBRUARY

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